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BRIDGING THE GAP BETWEEN EDUCATION AND RESEARCH THROUGH SOIL QUALITY TESTING

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Introduction

Large areas of northeast Oregon and southeast Washington first were cultivated in the late 1800s. These lands were highly fertile at first, but productivity declined with time. By the early 1900s, farmers were expressing concerns about lower yields, greater erosion, and higher production costs. Rasmussen et al. (1989) documented this degradation of soil, especially loss of soil organic matter, in the Columbia Plateau dryland cropping region. Yield increases since 1931 (Payne et al., 1997) due to improved technology have overshadowed loss in soil productivity.

Soil quality is defined as "the capacity of a specific kind of soil to function." In a cropping system, the function is to support and maintain plant growth. Assessment includes parameters related to the physical, chemical, and biological properties. Agricultural Research Service (ARS) and Natural Resource Conservation Service (NRCS) have developed a soil quality test kit (USDA, 1998). This test kit provides the equipment and instructions for evaluating soil respiration, water infiltration, bulk density, electric conductivity (EC), soil pH, aggregate stability, soil slaking, earthworms, water salinity, and nitrate/ nitrite levels.

The Pendleton Field Experiment Station was established in 1928 with the objectives of "maintaining soil fertility and developing more profitable crop production" (Pumphrey and Rasmussen, 1995). Several long-term experiments were established at the Experiment Station as early as 1931 and continue to operate. These and more recent long-term experiments at the Agricultural Research Center were used as a basis for this project.

The objectives of this project were to evaluate soil quality in long-term experiments at the Agricultural Research Center with the soil quality test kit and to develop secondary school work samples (curriculum units) based on the test kit equipment and procedures. The work samples would serve as tools to teach soil quality concepts and principles and help bridge the gap between agricultural education and research.

Materials

We used a soil quality testing kit marketed by Gempler's Inc. (P.O. Box 270, Belleville, WI 53508) and developed by USDA-ARS scientists as part of their mission to sustain natural resources by developing and disseminating information and technology. Four long-term experiments were evaluated with the test kit and eight curriculum units were developed for Oregon secondary educators. The long-term experiments evaluated included grass pasture (GP), continuous winter wheat (CW), winter wheat pea (WP), and no-till winter wheat fallow rotation (NTWF).

Grass Pasture (GP):

This site has been maintained since 1931. It is 150 feet wide and 360 feet long, and is dissected in the southern half by a drainageway. This site approximates near-virgin grassland. The dominant grass species is tall fescue. Vegetation is clipped once or twice during the summer growth, occasionally fertilized, and infrequently irrigated. Soil quality tests were conducted at three sites in the grass pasture.

Continuous Cereal (CW):

This experiment was established in 1931 and consisted of two adjacent sites on nearly level land (0 to 1 percent) cropped annually to winter wheat. One site is moldboard plowed, field cultivated, fertilized, and seeded, and the other site was changed to a no-till system in 1997. There are no replications in this experiment. Soil quality tests were made in four locations for each site. For statistical analysis, the two sites were treated as a completely randomized experiment with four replications and two treatments (no-till and moldboard plow based tillage system).

Wheat Pea (WP):

This experiment was established in 1963. It is located on nearly level land, and hosts a winter wheat pea crop rotation with four tillage systems. The experimental design is a randomized block with four replications. Two tillage treatments were evaluated. One treatment was fall moldboard plowed, and the other was minimum tilled (skewtread in the fall before peas and summer sweep tillage before winter wheat).

No-Till Wheat (NTWF):

This experiment was created in 1982 and is the newest long-term experiment. It is located on level land and was previously cropped to winter wheat fallow with conventional tillage (moldboard plowed). NTWF experiment has a no-till winter wheat fallow rotation, and the only tillage is by hoe-type openers used to create seed and fertilizer furrows.

Two adjacent experiments were designed to study the transition from intensive tillage to no-till. One of these experiments is identical to the 1982 no-till wheat fallow experiment, except it was initiated 15 years later in (1997). The other experiment has a traditional moldboard plow and rod-weed tillage system.

Treatments consist of nitrogen rates applied during winter wheat seeding. Treatments are replicated four times in each of these experiments in randomized block designs. For the soil quality tests, 0 and 120 lb N/acre treatments were selected for evaluation.

Soil in all experiments was a well-drained Walla Walla silt loam from 4 to 6 feet deep. Soil quality tests were conducted in July and August of 1999. Samples were collected randomly from each experiment, and six soil quality tests known as key indicators were made as outlined in the soil quality test kit (USDA, 1998). These included two water infiltration tests, pH, bulk density, electrical conductivity, and aggregate stability. Eight work samples (curriculum units) were developed and deemed appropriate for classroom learning and teaching. These units are: measuring soil quality, soil maps and mapping principles, infiltration, bulk density, electrical conductivity (EC), pH, earthworms, and water quality. A brief outline of the tests is shown in Table 1.

Results and Discussion

Table 2 summarizes test results from soil quality evaluations made in the six long-term experiments. The infiltration values indicate there is a problem with the technique. Most of the infiltration rates exceeded 30 inches per hour. That is not consistent with more accurate methods. Wuest et al. (1999) used a double ring infiltrometer and found infiltration rates in the same wheat fallow experiments ranged from 0.04 inches per hour in the intensive tillage experiment to 5.1 inches per hour in the 17-year no-till experiment. Infiltration rates for these tests (Table 2) were more than 10 times higher than Wuest et al. (1999) results. The single ring infiltrometer used in these tests does not limit flow to one dimension (vertical flow). Lateral flow in addition to vertical flow may account for the observed high infiltration rates. Even though the flow rates were high, low infiltration rates observed in moldboard plowed treatments in the continuous wheat and wheat fallow experiments were consistent with Wuest et al. (1999) findings.

Bulk density values were consistent with those taken in the long-term experiments and reported by Rasmussen et al. (1994). Bulk density measurements were taken in the top 3 inches of soil. It is very difficult to determine accurately the location of the soil surface, especially if there are large soil aggregates on the surface; consequently, the measured soil volume may be in error. Bulk density accuracy could be improved if the top 2 or 3 inches of soil were removed and bulk density measured in the next 3-inch soil layer. None of the experiments had bulk density values that indicated a surface soil compaction problem; e.g., values exceeding 1.3 g/cm^3.

Electrical conductivity (EC) values ranged from 0.08 to 0.25 dS/m. EC values from 0 to 0.98 dS/m indicate non-saline soil that has negligible effect on crop and organism effects (USDA, 1998). None of the experiments had EC values close to 0.98 dS/m, the upper limit of non-saline soils.

Aggregate stability in all experiments were low (Table 2). The most surprising result was 7 percent water stable aggregates (mean of three samples) in the grass pasture experiment. The rest of the experiments had aggregate stability values that ranged from 37 to 65 percent. Expected water stable aggregates for soil with 2 percent organic matter and clay content of 20 percent is 70 to 75% (USDA, 1998). Walla Walla soil series in the virgin grass land state has 2 to 3 percent organic matter and 15 to 17 percent clay (USDA, 1988). These water stable aggregates are considered macroaggregates (greater than 250µm).

Macroaggregates form readily under pasture or forage grasses, but the pasture soil had the lowest percentage of water stable aggregates in these tests. It appears that the last step in the procedure, which is designed to disperse aggregates with a Calgon® solution and separate sand from the aggregates, did not completely disperse the soil; consequently, some aggregates were considered sand. Using the data from the water stable aggregate determinations, the percent sand was 65 and 50 percent, respectively, in the pasture and wheat pea experiments. This much sand in a Walla Walla silt loam is not possible. Walla Walla silt loam has a sand content less than 15 percent (USDA, 1988) and the cropping system should not change the percentage of sand. Assuming 10 percent sand in both of these experiments and recalculating water stable aggregate percentages, the pasture would have had 75 percent water stable aggregates and the wheat pea experiment would have had 60 percent water stable aggregates.

The pH tests revealed a serious problem in the continuous winter wheat experiment. For the moldboard plow treatment, pH was 5.2, and no-till pH was 5.5. These values indicate a strong acid condition. Under strong acid conditions the availability of nitrogen, potassium, phosphates, and sulfur are greatly reduced. Pikul and Allmaras (1986) found repeated use of ammonium-based fertilizers lowered the plow layer pH in a long-term wheat fallow experiment at the Pendleton Research Center to less than 5.0. Wheat diseases, strawbreaker foot rot, and Fusarium foot rot were found to increase as pH decreased in these long-term experiments (Smiley et al., 1996). Wheat grain yields in these continuous wheat experiments would be expected to increase with liming. The rest of the experiments had pH values above 6.0 except for the high nitrogen rate in 17-year no-till experiment which had a treatment mean of 5.9. A suitable soil pH range for wheat is 5.5 to 7.0 (Whittaker et al., 1959).

In addition to serving the purpose of testing long-term plots, educational units for classroom teachers were created. It was hoped that we could offer teachers some useful information to give their students to create a better understanding of soils and their importance. Eight work samples were designed for understanding and measuring soil and water quality and for understanding soil survey maps. These work samples included the targeted benchmarks and CIM/CAM (Certificate of Initial Mastery/Certificate of Advanced Mastery) standards used widely in Oregon education today, as well as explicit directions, resources, and anticipatory sets. These work samples can be found at the Umatilla/Morrow ESD office in Pendleton, Oregon and may be checked out along with the Gempler’s Soil Quality Testing Kit.

Conclusions

A secondary school teacher and a high school student conducted these soil quality tests with limited background in soil science. The soil test kit guide served as the sole source of instruction for conducting the tests. The kit and instructions were found to be complete and easy to use for people not trained in the art and science of soil measurements. EC, bulk density, and pH tests gave meaningful data with three to four samples or replications.

Aggregate stability tests need to be evaluated, because apparent errors were introduced in measuring sand content for a silt loam soil. Possibly clarifications and/or modifications to the instructions would solve this problem. Infiltration measurements provided infiltration rates that were a factor of 10 or more higher than more accurate methods provided for the same experiments. Modifications to the infiltration procedures and equipment should be considered for conditions such as in the Columbia Plateau, where soil water is usually the limiting factor in crop production. The soil quality test kit can be extremely useful as an instructional tool in secondary schools to study soil processes and concepts.

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Table 1. Soil quality tests, procedures, and purposes used to evaluate long-term experiments at Pendleton, Oregon in 1999 and to develop secondary school work samples.

Test	Purpose	Procedure
Infiltration	Determine the rate that water enters the soil.	Drive a 6-inch diameter pipe into the soil. Measure the time it takes 1 inch of water to drain through the pipe into the soil.
Respiration*	Measure the amount of carbon dioxide (CO_2) given off by organisms and plant roots in the soil.	Collect gases emitted from the soil surface through the infiltration pipe 24 hours after infiltration tests, and measure the % CO_2 in the collected gas with a Draeger tube apparatus.
pH	Determine the acidity or alkalinity of a soil, which effects nutrient availability, biological activity, and solubility of soil minerals.	Make a solution of equal part soil and water, then measure pH with electronic meter.
Water Quality*	Determine the water salinity, nitrate and nitrite levels in drinking, pond, irrigation, or drainage water associated with agriculture.	Collect water samples, perform electrical conductivity, and measure nitrite and nitrate amount with nitrate/nitrite strips.
Earthworms*	Measure earthworm population. Earthworms generally increase microbial activity and fertility, and enhance soil physical properties.	Excavate a cubic foot of soil and count the number of worms found in the excavated soil.
Bulk Density	Determine the dry weight of soil per unit volume. This is an indicator of compaction.	Drive a 3-inch diameter tube into the soil. Remove the tube containing soil and measure the volume and dry weight of soil removed.
Electrical Conductivity (EC)	The electrical conductivity measurement detects the amount of salts in soil solution.	Mix a solution of equal parts soil and water, and then measure EC with a handheld meter.
Aggregate Stability	Measure the vulnerability of the soil aggregates to external destructive forces.	Wet sieve soil aggregates and measure the proportion of dry aggregates that will not pass through a 0.25 mm sieve.

* Indicates tests included in developing work samples (curriculum units) but not used to evaluate long-term experiments.

Table 2. Observations made in long-term experiments at Pendleton, Oregon in July and August, 1999 with a soil quality test kit.

Experiment	Treatment	Infiltration First† App.	Infiltration Second App.	Bulk Density	EC	Aggregate Stability	pH
		inches/hour		g/cm^3	dS/m‡	%	
Grass Pasture	Mean	207	55	1.2	0.12	7	6.4
	Std. Dev§	165	68	0.17	0.12	8	0.25
	CV††	80	124	14.0	100	114	4
Continuous Winter wheat	Plow	29	7	0.78	0.23	49	5.2
	No-till	63	17	0.88	0.18	48	5.5
	S.E.||	36	9	0.08	0.07	13	0.25
	Sig.†††	ns	ns	ns	ns	Ns	ns
Wheat fallow							
1st yr No-till	0-N#	12	1	1.1	0.10	50	6.4
	120-N	517	37	0.6	0.15	60	6.3
	S.E.	346	17	0.12	0.02	9	0.09
	Sig.	ns	ns	ns	ns	ns	ns
17-yr No-till	0-N	252	92	0.8	0.10	46	6.4
	120-N	353	63	0.8	0.08	37	5.9
	S.E.	225	69	0.05	0.01	10	0.13
	Sig.	ns	ns	ns	ns	ns	ns
Moldboard Plow	0-N	75	2	1.1	0.25	65	6.1
	120-N	126	3	0.9	0.20	45	6.2
	S.E.	39	1	0.14	0.03	5	0.12
	Sig.	ns	ns	ns	ns	ns	ns
Wheat Pea	Fall till	56	18	1.09	0.17	47	6.7
	Min till	113	31	1.08	0.16	41	6.2
	S.E.	27	9	0.01	0.01	4	0.10
	Sig.	ns	ns	ns	ns	ns	ns

† First application measured infiltration rate for first inch of water, and the second application measured infiltration rate for the second inch of water.
‡ A unit of electrolytic conductivity (EC), dS/m = decisiemens per meter
§ Std. Dev. = standard deviation
|| S.E. = Standard error of a mean
Rate of nitrogen applied during crop year. 0-N = 0 lb/acre and 120-N = 120 lb/acre.
†† CV = coefficient of variability = (Std. Dev./mean)100
††† Sig. = Statistical significant (P α 0.05).